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REDUCED WEIGHT AND COST IN SMART FORK-LIFT USING NITI ONE WAY HELICAL SPRING

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ABSTRACT

In this prescribed work, smart fork-lift has been discussed based on NiTi intelligent helical spring. The purpose of this work is to introduce the new concept of replacing hydraulic-based, pneumatic pressure -based, gearing and pulley-based systems mainly costing due to their precise mechanical design. Here, SMA technology was used which is one of the most promising candidates for various advantages like simplicity, compactness, optimal strength, high power to weight ratio, noiseless operation, non-soldering, non-magnetic, high fatigue resistance to cyclic motion etc. and made interesting to develop this thermo-mechanical model mainly based on shape memory effect. The system model is mainly based on NiTi intelligent helical spring and comprised of bearings, aluminum wheel, Temperature sensor, load cell, DPM's, DC Supply unit, channel rods, basic electric-electronic components etc. The annealing and normalizing processes are also applied on SMA. The analysis of variation of deflection with respect to temperature, current values with respect to scale value of strain obtained and load capacity with respect to temperature are considered.

KEYWORDS: Annealing, Intelligent Helical Spring/SMA, Normalizing & Smart Fork-lift

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Original Article

1. INTRODUCTION

The technology evolution for smart materials plays a vital role in replacing the conventional materials. William Buehler an American supervisor working in the U.S. Navy discovered an alloy of Nickel and Titanium, which are mainly mixed with the composition of Ni-45% Ti-55%, Ni-55% Ti-45%, Ni-50% Ti-50%. The word Nitinol is introduced from the laboratory name and is commonly named as Ni-Ti alloys [5]. These materials are also known as the SMA's or smart Metallic materials. SMA's are the materials, which remember the original shape of the material, and it can regain its shape when it is subjected to heat, magnetic variation. SMA's are of various types such as high temperature SMA, magnetic SMA, shape memory thin film, shape memory polymers and many more. The smart metallic materials which have especial or unique properties as shape memory effect, phenomenology of phase transformation in shape memory alloys, pseudo elasticity, one-way force, bias mechanisms in SMA actuators, cycling effects, hysteresis and non-linearity[8]. Shape memory alloys (SMAs) have been implemented in several high-performance applications requiring high work densities, high strength, eco-friendly environment, non-corrosive environment, large recoverable

deformations, high stresses and good biocompatibility. Nowadays shape memory alloys have become excellent candidates towards micro-miniature system. The MEMS/NEMS is the integration of mechanical elements, sensors, actuators SMAs which are NiTi-based having much attention in the rapidly growing field of micro-electro-mechanical-systems (MEMS). The most commonly used copper- based SMA's are of Cu-Zn-Al, Cu-Ni-Al. As copper is used this type of SMA's these are used in security application, thermal applications. Iron based SMA's were introduced with compositions like Fe-Mn-Si, while Cr, Co enhances the corrosion resistance. The shape memory effect consists of two phases- first is the martensite state and the austenite state. The austenite state occurs mainly at high temperature while the martensite state occurs at low temperature or room temperature. Ni-Ti alloy is most commonly used due to its good properties, bio-compatibility and many more. The shape memory effect of this alloy is upto 8% at temperature range of 0 to 100º C[10] If we talk about the one-way effect of smart metal, the effect of shape recovery in one direction only, in regarding of that a constitutive "one-dimensional phase transformation model" in which analytical investigation of strain loading frequency effect on stress-strain-temperature relationship of shape-memory alloy was described[9]. The factors affecting the temperature variation depending on loading frequency were analytically investigated from the formula. Furthermore by considering the fabrication and manufacturing technique of thin-film and bulk micromachined SMAs, the main features such as material properties, transformation temperature, material composition, and actuation method are also represented. The application and micromechanism for both thin-film and bulk SMA are described [2]. Focusing on the low weight and portable actuators with shape memory alloys introduced the new concept of high-resolution and low cost tactile display. He used the 2-D tactile displayed and also included camera, computer and electronic module, electronic drive with tactile shapes. He first designed as a prototype model which consists of an array of 8/8 upward/downward independent moveable pins based on shape memory alloy (SMA) technology [7]. R-phase SMA helical springs taken into account for detwinning and assisted two-way memory effect are proposed and validated. R-phase shape memory alloy helical spring based actuators for modeling and experiments. This contribution analyses the quasi-static thermo-mechanical behavior of SMA helical spring-based actuators. In a primary step, analytical or pseudo-analytical tools had been proposed to describe both pseudo-plastic and stress assisted two-way memory effect behaviors of SMA helical springs. First, simplified models (i.e., based on beam theory framework) of. Then, these models were used to determine the thermo-mechanical behavior of a linear bias-spring actuator. An actuator was builted and used to validate the proposed models [1]. On the experimental study of helical shape memory alloy actuators Shane J. considered the effects of design and operating parameters on thermal transients and stroke. The parameters included as wire diameter, spring diameter, transition temperature, number of active turns, bias force and direct current magnitude. In their helical SMA actuator behaviour and dynamic Outputs they includes reaction times, elastic stroke model, constitutive model, effective stroke model, and static two-state model initially[3]. Laser-induced shock wave imprinting appeared to be strong candidate to replace nanoindentation to obtained two-way shape memory effect [6]. Study on Laser-Induced recoverable surface patterning on Ni50Ti50 Shape Memory Alloys also discussed [4]. Vacuum induction melted Ni50Ti50 shape memory alloys were cut into circular plates with a diameter of 10 mm and thickness of 1 mm by electrical-discharge machining method. The surface roughness of the samples was reduced to 0.05 µm in five steps by using Buehler EcoMet 250 Grinder-Polisher with an AutoMet 250 Power head. Overall, two different, low cost, relatively fast, and highly scalable laser-assisted imprinting techniques for micro-patterning of metallic alloys, in particular NiTi shape memory alloys were reported. Transformation temperatures were determined by using

a Perkin-Elmer Pyris 1 differential scanning calorimeter (DSC). The martensite and austenite start and finish temperatures (Ms, Mf, As, and Af, respectively) were 78 °C, 45 °C, 85 °C and 122 °C for the these sample.

2. MODEL PREPARATION

The proposed model of smart fork-Lift comprised of the following main sub-parts included as:

2.1 Bearings (4-pieces)

Alloy steel balls have been used here; bearing-balls are special highly spherical and smooth in performance with negligible friction coefficient and 9 in numbers. Reducing friction in bearings is often important for efficiency, to reduce wear and to facilitate extended use at high speeds and to avoid overheating and premature failure of the bearing, so the bearing material used here as graded steel.

Specification as-Received: Table 1 (Stainless Steel Bearings)

Outer Diameter /Bore Diameter	17mm/7.5mm	Enclosure	one-shield
Contact angle	10^0-25^0	Ball/Bearing Material type	Alloy steel
Slot depth	1.5mm	Weight per piece	40gm
No. of Balls	9	Width	8mm

The figure 1 having 4-bearngs and the specification of one bearing can be seen from table 1. The bearing ring and rolling elements subjected to repetitive high pressure with as small amount of sliding. The cages are subjected to tension and compression and sliding contact with rolling element and either or both of the bearing ring.

Figure 1: (Alloy Steel Bearing).

2.2 Steel Round Bar (2-pieces)

Cylindrical type of stainless steel round bars or rods are used in which the length of each rod equal to 30cm and diameter of each cylindrical rod equal to 6mm respectively. These used in vertical position such that ball bearing can be moved over these rods with a smoothly manner and without tilting. The coefficient of friction between rod and balls of bearing considered as negligible and the contact angle between rod and balls of bearing also should be lie in the range of 10^0-25^0. Both the cylindrical rods welded with the help of 400amp TIG welding machine to vertical channel in outer end sides it. The height of scale and the height of vertical channel also equal to the height of cylindrical rods.

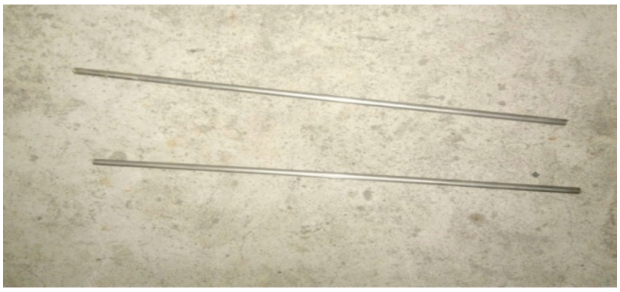

Figure 2: (Stainless Steel Round Rods)

Stainless steel round bars were cut in size to 30cm as per requirements. They are available in non standard sizes in both Metric and Imperial with wide variety of grades, Simple grades are including as 303, 304, 316, 321, 410, 420 and 431. We have used the commonly applicable metric stainless steel round bar of grade 316.

2.3 Channels (Iron and Aluminum based)

The iron-channel used as vertical scale and positioned vertically. It has one flat face and other zigzag backward face as shown in diagram, it also having holes on the flat face centrally at equidistance along lengthwise. It is named as Vertical iron-channel. The holes define the purposed of tightening or joining it to other suitable parts or devices. The length of vertical channel = 30cm, Thickness of vertical channel = 3.25mm and width of vertical channel = 4.2cm respectively.

Figure 3: (Channels)

The aluminum-channel used as horizontal base and positioned horizontally. Its shape like sandwich type which having almost two flat end faces and hollow space between two end faces such that desire nuts or screws can be provided as per need on top face, so it is named as Horizontal base-channel. The length of horizontal channel = 32.6cm, Thickness of horizontal channel = 1.0mm (in end faces) and width of horizontal channel = 11.4cm respectively.

2.4 Helical Compression-Springs (Spring Steel)

Two helical compression springs have been used which made of spring steel material. We used the low- alloy manganese type with other alloying element nickel also presented as prescribed by the seller.

Figure 4: (Spring Steel)

This allows objects made of spring steel to return to their original shape despite significant deflection or twisting. Spring steel is also commonly used in the manufacture due to its resistance to bending, snapping or shattering. The dimensions of each spring included as thickness of helical compression spring = 1.25mm, pitch of helical compression spring = 6.75mm, free length of helical compression spring = 35.0mm, numbers of Active coil = 04 and total number of coil = 08.

2.5 Load Cell (0-3.0Kg)

The load cell had placed on the bottom face of the aluminum channel by simply fixing with the help of two sets of nuts & screws. The Iron plate had maintained in fixed position so the load cell has been remained in rested position also.

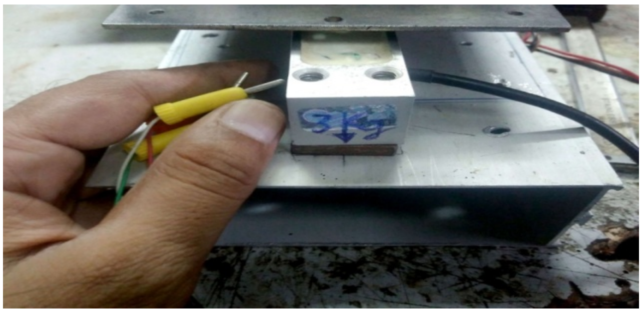

Figure 5: (Load Cell in Placed Position)

For the better accuracy, straight bar load cell has been applied here, range from 0-3.0 kg of force. This straight load cell sometimes called a strain gauge or HT sensor. If we want to relate the electrical resistance (R) to the mechanical strain (ϵ), then we have to evaluate the GF or SF (GF refers to Gauge factor/ Strain Factor)

Specification as-Received: Table 2: (HT Sensor)

Measuring Range/Rated capacity	0-3.0 Kg	Rated output	1 mV/V
Non-Linearity	0.15 % F.S.	Recommended Excitation Voltage	12 V
Gauge factor	2 – 5	Metal Film/ Metal Foil	Constantan/Silicon

$$[GF = \frac{\Delta R/R}{\Delta L/L} = \frac{\Delta R/R}{\epsilon} = 1 + 2\nu + \frac{\Delta\rho/\rho}{\epsilon}]$$

Where E = Strain $=\Delta L/L$, ΔL = absolute change in length, L = original length, ν = poisson's ratio, ρ = resistivity, ΔR = Change in strain resistance due to axial & lateral strain & R = unstrained resistance of strain gauge.

2.6 Temperature Sensor (LM35)

The LM35 temperature sensors series are precision integrated-circuits which provide output voltage is linearly proportional to the Celsius temperature. So temperature value measured with respect to volt (V) here.

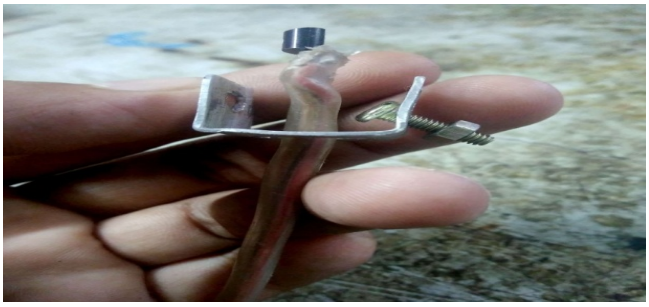

Figure 6: (LM35).

The proper connection has been used of LM-35 temperature sensor & indicated the digital value practically when body of active surface (black) glued or consistently touched within the working SMA. One temperature sensor had placed at nearer to the fixed socket-terminal with the help of aluminum small plate in which mouth of if adjusted and small plated screwed onto the Iron based vertical channel.

Specification as-Received: Table 3: (LM35- 2 pieces)

Operating range	4-20 volts	Non-linearity	±1/4°C (typical)
Rated range	-55° to +150°C	Self-heating	0.08°C (Still air only)
Linear scale factor	+10.0 mV/°C	Material ICs	Silicon
Colour/Body	Black	Connecting point / Connectors	Three (3) (A 4-20 Volts, B Output, C GND)

The three terminal of temperature sensors included for voltage in volts as first, output as second and ground (GND) as third had considered. The terminal wires were covered with body of PVC material with the help of hot gun to avoid temperature effect accounting due to wiring or nearby temperature effect.

2.7 Transparent Acrylic Box

It is a Poly-methyl-methacrylate or PMMA also known as acrylic, acrylic glass which called its trade name. The transparent Plastic sheet separated from the glass acts as a polymer. It is often preferred because of its especial properties as light-weight, easy handling and processing, Non-modified behaves in a brittle manner when under load and low cost. It is one type of transparent-thermoplastic also often considered in sheet-form as moderate-scratchable and moderate-impactable with shatter-resistant alternative.

Figure 7: (Acrylic Box).

The dimensions of open-type acrylic box which was transparent as for Bottom base sheet (cube type): - base thickness of sheet = 4.30mm, length of sheet = 102.60mm, width of sheet = 103.80mm-8.60mm = 95.20mm i.e. (102.60x95.20x4.30). For Back vertical face sheet (made by combined of two acrylic sheets of same configuration and act also as cube):- vertical height of sheet face = 63.80mm, thickness of vertical sheet = 8.60mm, length of vertical sheet = 102.60mm i.e. (102.60x63.80x8.60). For side acrylic sheet (two sheets act as trapeziums):- parallel sides as small side = 7.60mm, large side = 63.80mm and non-parallel sides as one side = 95.20mm, other side = 146.20mm.

2.8 Power Supply Circuit (5V)

Three power supply circuits had applied one for atmospheric temperature sensor, second for DPM-I and third for DPM-II. The SMA sensor connected with one DPM supply at which we received SMA temperature. Each circuit consist sets of four diodes of IN4007 which were used to made bridges in the circuit as shown in figure 8. Three sets of transformers 0f 18V output used here. Other equipments in each circuit also includes three regulator7805(fixed types), three set of capacitors in which each set having again three capacitors configuration as one set of 25V/2200mF configuration and second set of 63V/1mF configuration and third set of 0.1mF configuration. The 10k ohms three registers and one preset also used.

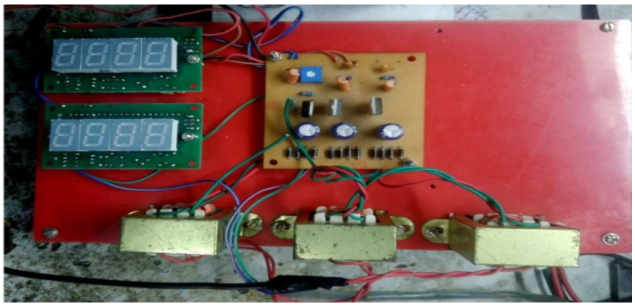

Figure 8: (Power Supply Circuit).

2.9 Load-Amplifier Circuit with DPM

(Operational): The Previously used circuit has been applied here which used in paper to prepare stress evaluation Technique-Cum-Model of intelligent helical spring SMA with practical illustration that enables the stability of SMA & design of spring. Load cell had the attachment with strain gauge measuring kit which is basically amplifier circuit which involves the IC 7107.

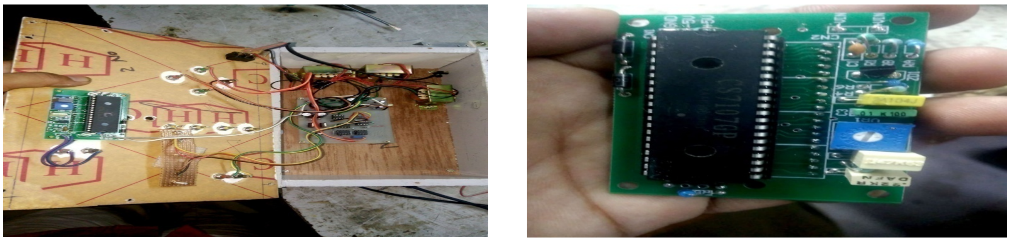

Figure 9: (Operational Amplifier Circuit with Digital Panel Meter).

Panel meters are instruments that display an input signal in an analog or digital form. Many panel meters also include alarm options as well as the ability to transfer data to a computer. A high performance and low power consuming integrated circuit (IC) 7107 that consists of seven segments decodes, reference voltage source, comparator and display drives as its internal circuiting and description of 40 pin. Digital output value = 0-1999 (upto 2 volts), drive display = 7 segment drive, no. of pin = 40. No. of LED in segment = 07. It is one type of analog to digital circuit.

2.10 Pulley and Supports (Al-Based)

Aluminum pulley used is a wheel on an steel bearing which is fixed onto a threaded that support movement and change of direction of a steel-wire and transfer of load between SMA and acrylic box, The supports were provided for right positioning of pulley which also made of aluminum can be seen in figure 10. We have also used four nuts for the tightening of supports in present component. This component was used material of aluminum because of light weight, high strength, dimensional accuracy and robustness.

Figure 10: (Pulley and Supports).

The dimension of pulley as: diameter = 37.20mm, thickness = 10.0mm and groove size includes as centered slot depth = 1.5mm, centered slot width = 3.0mm. The dimension of supports (channel- type) as: total length of each support = 56.50mm, thickness of each support = 2.50mm. The dimension of screw and nuts as: bore diameter of screw = 8.0mm, pitch of screw = 1.25mm, final length remaining after cutting = 41.50mm and for 4-nuts, bore diameter of each nut = 8.0mm, pitch of each nut = 1.25mm, outer diameter of each nut = 12.50mm. The Hexagonal nuts were used and channel types supports were also used for further fixing of this component.

2.11 Socket Terminal Connectors (2-pieces)

The load carrying specimens were used in which we connect the end of SMA helical spring in which one remained in fixed position and other remain in adjustable position. These specimens carry the which lifted in this present forklift. Surfaces of

each terminal grooved by triangular file such that the steel wires could br wound up for the hanging purpose.

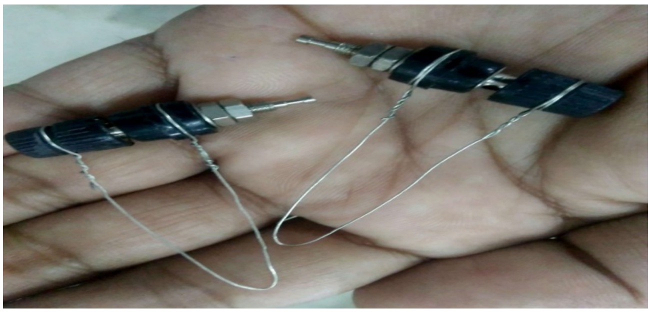

Figure 11: (Socket Terminal Connectors).

7.3.12 Additional Parts/equipments

- *DC Supply (15V/5A*
- *Hanging wire (steel)*
- *Multimeter(digital)*
- *Hot-air gun (2000W)*
- *Allen keys(Hard-steel)*
- *Digital caliper (stainless steel)*
- *Ruler-scale (steel/30cm):*
- *Basic electrical-electronic components:*
  - Resistors(1k-10k)
  - Capacitor(1000mf/25v,1mf/63v)
  - Diode(Electrolytic)
  - Inductors(coil/wound)
  - Transistors(3terminal-based)
  - Rectifiers(Bridge-type IN4007)
  - Transformers(Set-down909)

7.4 Material & SMA Helical Spring

The metallic material of spring wire is NiTi alloy or Nitinol having trade name flexinol which behave as smart material used here. The one way SMA was purchased in the form of wire from the thing bits electronics Pvt. Ltd. as in drawn condition. As per received informing about SMA in composition as 49% Nickel and 51% Titanium with one way shape memory alloy and produced by vacuum induction melting. The flexinol wire of dia 1.0 mm, the manufacturing of SMA helical spring used the

threaded screw, end restraints and mild steel fixture with copper clamping wire. The muffle furnace was utilized for the tolerance of ±5°C and muffle voltage regulator preset at 530°C for 45 minutes to made typical helical spring with mean coil dia. of 7.4 mm & ‘8’ no. of turns the annealing process was firstly applied by switch off the muffle furnace then normalized for 6 hours by just opening of muffle furnace gate and removing the helical spring after 24 hours

Figure 12: (Muffle Furnace with Infrared Temperature Sensor).

The digital Infrared temperature sensor was also used in between the reading of working-temperature of muffle furnace before to reach at preset condition of 530^{o}C. The Infrared Temperature sensor helps to define the accuracy of working-temperature of muffle furnace.

Figure 13: (Final NiTi-based SMA Helical Spring).

The parameters obtained as :(D) Mean coil diameter = 7.4 mm,(d) Wire diameter = 1.0 mm,(n) No. of turns = 8,(c) Spring index = D/d=7.4,($L_{initial)}$ Initial free length of spring = 2.5 cm. These are the basic parameters, its related detailed of manufacturing concern point of view nearly same in terms of Threaded Screw, END restraints, Steel Fixture and Clamping Wire. So thoroughly presented in paper in universal review journal on design and correlations of shape memory alloy intelligent helical spring by differing the constant temperature and diameter for a mechanical actuator, March 2019 vol 8(3), in which 1.0 mm diameter SMA has been used but parameters are significantly different although set of heat treatment condition & manufacturing of SME helical spring procedure were almost same.

7.5 Experimental Setup

It can be seen from figure 14, 1.0mm SMA wire was considered for analysis of NiTi-based helical spring in which ends had attached with two socket terminals. Although one socket terminal had maintained fixed on vertically placed iron-channel and this socket so tightened that not be tilted during the loading or unloading of NiTi-based helical spring. Then the other end of NiTi SMA had attached with another socket terminal which maintained in freely condition such that its position movable with

respect to fixed socket terminal but movement depend upon the preset length of SMA. Preset length condition of SMA helical spring wire represents the vertical length of spring or we can say the free length of SMA helical spring. The previously prepared stress- model has used which discuss in presented paper i.e. to prepare stress evaluation Technique-Cum-Physical Model for intelligent helical spring SMA with practical illustration.

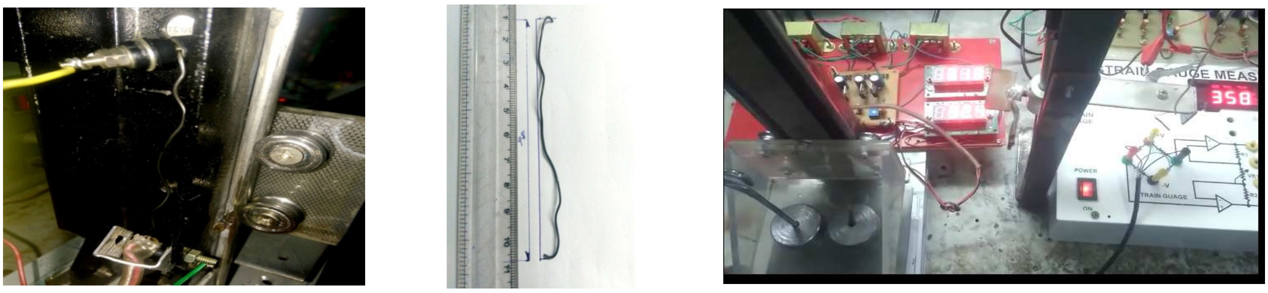

Figure 14: (Smart Fork-Lift Setup).

We used only strain gauge part of stress evaluation Technique-Cum-Model for scale-value determination and load calculation because load-cell arrangement was implemented in this smart fork-lift. Temperature sensor LM35 had attached with the zigzag backward face side of iron-channel. The operational amplifier circuit with digital panel meter connected to the load-cell and two helical compression springs have been used which made of spring steel material placed on the load-cell platform. Three 5-V DC power supplies had employed in this smart fork-lift as one for the Temperature sensor LM35 for atmospheric-temperature, second for digital panel meter First and third for other digital panel meter. The SMA sensor connected with one digital panel meter at which we received SMA temperature

7.6 RESULTS AND DISCUSSIONS

7.6.1 Scale-Value Calculation

The scale values have been calculated with the help of acrylic box of smart fork-lift and steel weights which were placed on this box one by one. The steel weights of each piece also equal to 100gm. The total 200gm weight has been applied. The acrylic box has 170gm (Approx.) of weight which define by GF value equal to 290. Steel weight has 100gm of weight which also define by GF value equal to 172, similarly for 200gm weight equal to 174 respectively.

Table 4: (Average Scale Value)

Sl. No.	Weight Acrylic Box(gm)	Load-Cell Strain or GF Value	Atm. Temperature(^{0}c)	Difference Value	Related Value
1	0	290	28.9	290	Nil
2	100	462	29	172	100/172 = 0.581
3	200	636	28.9	174	200/346 = 0.578
	Avg. Scale Value		**(0.581+0.578)/2 = 0579**		

So, Average scale value provided the weight in term of strain or GF value which used in further calculation. Average scale value for weight as: "**1gm = 0.579**"

7.6.2 Main Observation Data

The NiTi SMA helical spring one end had attached with one socket terminal and other end connected to another socket terminal. Although one socket terminal had maintained in fixed position on the vertically placed iron-channel such that it should not tilted during the loading or unloading. Preset length condition equal to 9.8cm of SMA helical spring wire represents the vertical length of spring

Table 5: 7.6.2 (Observation Data)

Table 7.6.2 (observation data)

Sr. No.	Preset Length(L) (cm)	Voltage Applied(V) (volts)	Avg. Current in wire (Amp.)	Atm. Temperature (^{0}C)	Avg. Wire Temperature (^{0}C)	Vertical scale Reading(mm)	Load-lifted (cm)	Avg. Load-Cell Strain or GF value	Spring-load value (gm)
1	9.8	0	0	28.9	29	17.6	0	810	470
2	9.8	1	0.42	28.9	29.4	17.2	0.4	0	0
3	9.8	2	0.8	29	30.6	16	1	0	0
4	9.8	2.5	1.6	29	31.8	14.9	2.7	0	0
5	9.8	3	3.2	28.9	33.2	13.4	4.2	0	0
6	9.8	3.5	4.3	28.9	34.1	10.1	7.5	0	0
7	9.8	4	5.1	29	35.75	10.4	7.6	0	0
8	9.8	4.5	5.7	29.1	37.5	10.4	7.6	0	0
9	9.8	5	6.3	29	39.8	10.4	7.6	0	0

The observation table comprised of current produced in SMA wire, Vertical scale reading Load lifted Atmospheric temperature during experimental work, Gauge factor value during the voltage applied. Generally all reading depend upon the voltage applied, so very precisely increasing of voltage was done for the Preset length equal to 9.8cm for the NiTi-based SMA helical spring. It can be seen from the figure 7.6.2, various constraint of smart fork-lift have been graphical showed.

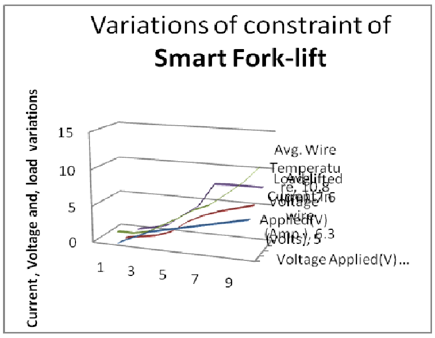

Figure 15: (Constraint of Smart Fork-lift).

The graph between Loads lifted V/s Voltage applied represents the intermediate values of voltage applied showed the maximum actuation of SMA. If we talked about the end region of voltage increment, that replied little bit actuation of SMA.

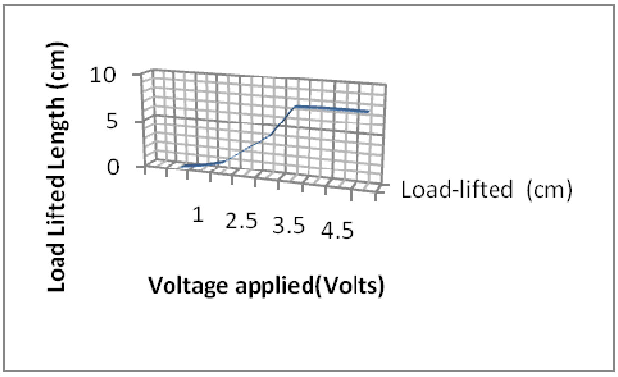

Figure 16: (Load Lifted V/s Voltage Applied).

The graph between Loads lifted V/s working SMA Temperature can be seen in figure 7.6.4 which replied to us intermediate values of temperature showed the maximum value for SMA. If we talked about the end region of voltage increment, that replied no variation of temperature for SMA. The load lifted as per data received nearly equals to the 470gm upto the height of 7.3cm length on the vertical scale. The Average scale value reading was obtained i.e. 810 with the help of the strain gauge measuring circuit.

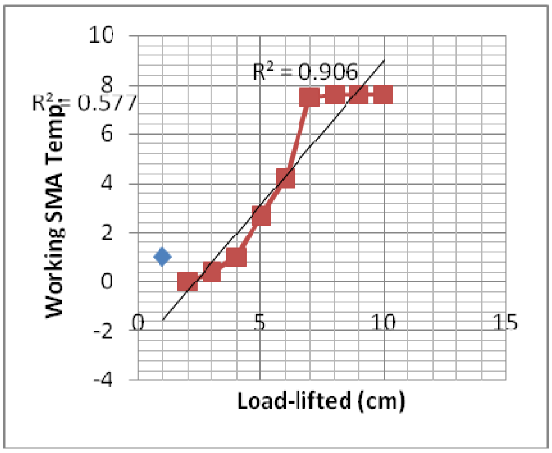

Figure 17: (Load lifted V/s Working SMS(Temperature)

The Correlation coefficient obtained as $R^2 = 0.906$ which represents the linear relations with respect to variables on respective axis's.

Validation of Result

In the previous Stress evaluation-technique-cum-model for intelligent spring showed the loading capacity upto 1.42Kg of load capability of NiTi-based SMA wire (o1.0mm diameter)

7.7 CONCLUSIONS

This Smart fork-lift provide the atmosphere to replace hydraulic-based, pneumatic pressure -based, gearing and pulley-based systems mainly costing due to their precise mechanical design as an actuator. Here voltage applied showed the maximum

actuation of SMA, but the end region of voltage increment, that replied little bit actuation of SMA. Correlation coefficient obtained as R2 = 0.906 which represents the linear relations with respect to variables on respective axis's. The intermediate values of temperature showed the maximum value for SMA, but end region of voltage increment, that replied no variation of temperature for SMA.

This prescribed worked will support to researchers for developing an environment based on thermo-mechanical model of Fork-Lift mainly by using NiTi metallic materials as shape memory effect.

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